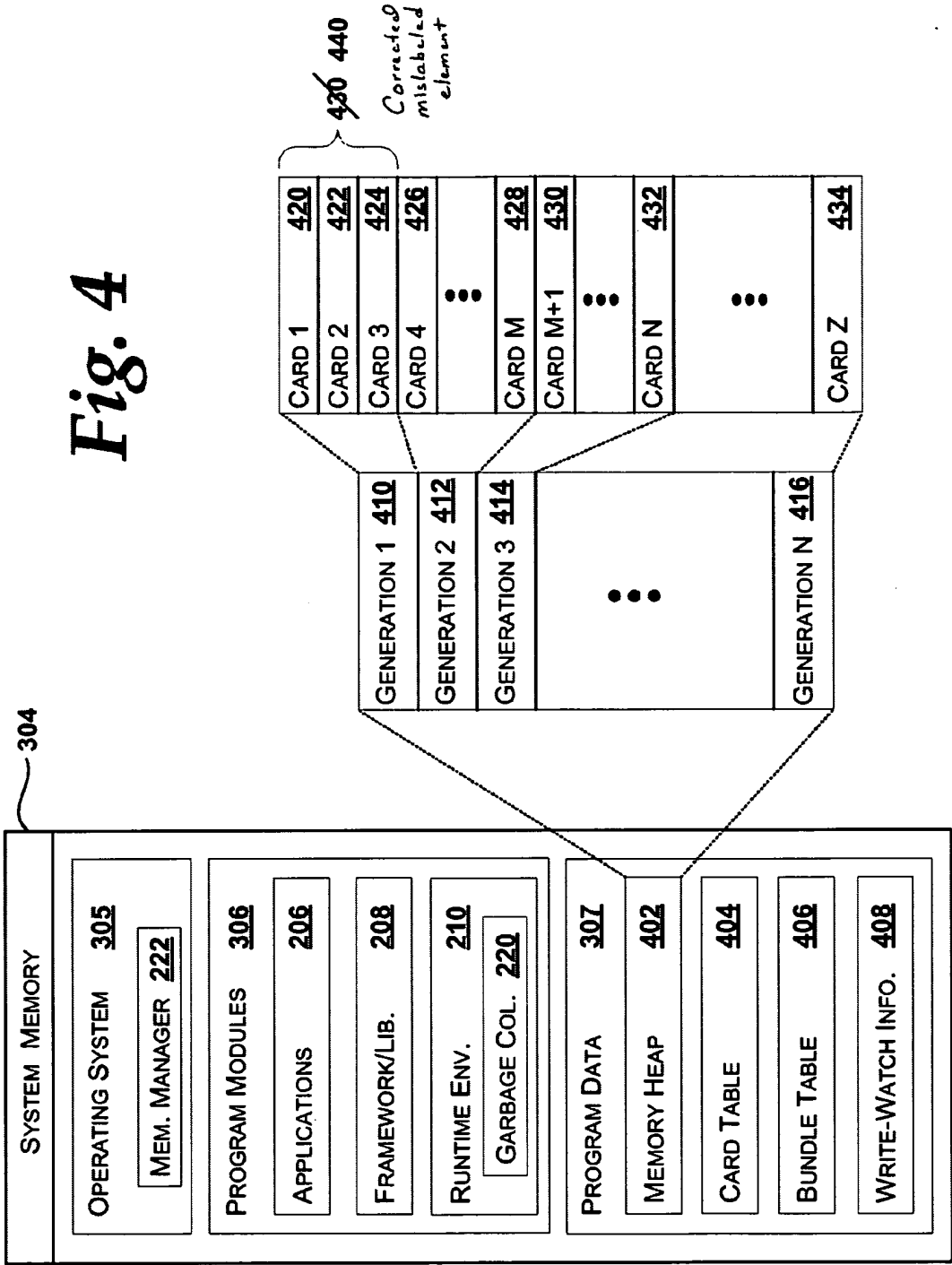


AMENDMENTS TO DRAWINGS

The attached sheet of drawings includes changes to Figure 4. This sheet replaces the original sheet for Figure 4 which incorrectly identified a bundle with reference numeral 430.

Attachment: Replacement Sheet for Figure 4
 Annotated Sheet for Figure 4 Showing Changes



REMARKS

The Office Action of May 5, 2006, has been carefully considered. Claims 1-24 are pending in the application. Each of the objections and rejections in the Office Action are addressed in the following remarks. In view of the following remarks, Applicant respectfully requests reconsideration and allowance of the subject application.

Objection to Title

The title of the invention was objected to as not being descriptive. The Examiner required a new title that was clearly indicative of the invention to which the claims were directed. The current title is "System and Method for Performing Garbage Collection on a Large Heap". The Applicant has amended the title to "Ephemeral Garbage Collection Using a Tracking Mechanism on a Card Table to Determine Marked Bundles". Therefore, the Applicant respectfully requests withdrawal of this objection.

Objection to Specification

The specification was objected to as failing to provide proper antecedent basis of the claimed subject matter. The Examiner stated that the subject matter in Claim 18 that recites "tracking is performed on an initial access to the card table memory and not upon subsequent accesses to the card table memory" did not appear in the Applicant's specification. The Applicant disagrees with the Examiner. However, the Applicant has amended the specification to clarify that more than one memory location can be tracked. This amendment is supported throughout the specification (see paragraph [0017], line 4 – states "tracking

modifications to specified memory locations”). In addition, the present amendment to Claim 18 removes the language that resulted in the above objection. Therefore, the Applicant respectfully requests withdrawal of this objection to the specification.

Amendments to Figures

Upon reviewing the present application, the Applicant became aware that an incorrect reference numeral was identified on Figure 4. Reference numeral 430 associated with the bracket around Card 1 420, Card 2 422, and Card 3 424 should be reference numeral 440. This is supported in the specification in paragraph [0028] which states “pre-determined cards (e.g., 420-424) are grouped into a plurality of bundles (e.g., bundle 440). Therefore, this amendment to the drawings does not add new subject matter to the application and the Applicant respectfully requests acceptance of this drawing amendment.

Claim Rejections Under 35 U.S.C. §101

Claims 1-11 and 19-24 were rejected under 35 U.S.C. §101 as being directed to non-statutory subject matter. Specifically, the Examiner stated that Claims 1-11 were not limited to tangible embodiments and that Claims 19-24 recited both an apparatus and the method steps of using the apparatus. Claims 1-11 were amended to recite “the computer-readable medium being accessible by a computing device”. Thus, in order for the computing device to access the computer-readable medium, the computer-readable medium is limited to tangible embodiments. Claims 19-24 were amended to overcome the above rejections. Therefore, the Applicant respectfully requests withdrawal of this claim rejection.

Claim Rejections Under 35 U.S.C. §112, first paragraph

Claim 18 was rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the written description requirement. As discussed above, even though the Applicant contends that the specification did support the originally filed Claim 18, the amendments to the specification and the amendment to Claim 18 now makes this rejection inapplicable. Therefore, the Applicant respectfully requests withdrawal of this claim rejection.

Claim Rejections Under 35 U.S.C. §112, second paragraph

Claims 19-24 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite. The Examiner stated that these claims recite both an apparatus and the method steps of using the apparatus. Independent Claim 19 and dependent Claims 20, 22-24 have been amended to overcome the above rejections. Therefore, the Applicant respectfully requests withdrawal of this claim rejection.

Claims 22-24 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite. The Examiner stated that there was insufficient antecedent basis for the “computer-readable medium” recited in the preamble of each of the claims. The Applicant has amended this typographical err in Claims 22-24 and replaced “computer-readable medium” with “system”. Therefore, the Applicant respectfully requests withdrawal of this claim rejection.

Claim Rejections Under 35 USC §102(b)

Claims 1-4, 6, 8, and 19-22 were rejected under 35 U.S.C. §102(e) as being anticipated by U.S. Patent Application Publication 2004/0003014 to Nagarajan et al. (hereinafter referred to as the Nagarajan reference).

In overview, in order for prior art to anticipate a claim under 35 U.S.C. §102 every element of the claimed invention *must be identically disclosed* either expressly or under principles of inherency in a single reference. Further, the exclusion of a claimed element from a prior art reference, no matter how insubstantial, is enough to negate anticipation by that reference. The test of whether anticipation exists in a particular case is a question of fact, and is applied element-by-element to a single prior art reference. Only if the prior art literally reads on every element of the rejected claim will the claimed invention be anticipated under this test.

With this in mind, the Applicant analyzes the §102 rejection of the claims in the present application.

Claim 1 has been amended to clarify the elements that are not disclosed by the Nagarajan reference. For convenience, Claim 1 is reproduced below with portions in bold to better emphasize some of the elements that are not disclosed in the Nagarajan reference.

1. A computer-readable medium having computer-executable instructions for performing ephemeral garbage collection, the computer-readable medium being accessible by a computing device, the instructions comprising:

requesting a list from a tracking mechanism, the list identifying memory locations that have been written into since the last ephemeral garbage collection, each memory location corresponding to one of a plurality of cards associated with a card table, each card being associated with one or more objects allocated from within a memory heap;

identifying at least one marked bundle based on the list, wherein the marked bundle represents a subset of the plurality of cards;

for each marked bundle, determining at least one marked cards within the marked bundle;

for each marked card, determining at least one accessed object within the marked card; and

performing garbage collection upon the at least one accessed object.

As shown above, amended independent Claim 1 recites **“requesting a list from a tracking mechanism, the list identifying memory locations that have been written into since the last ephemeral garbage collection”, “each memory location corresponding to one of a plurality of cards associated with a card table”, and “identifying at least one marked bundle based on the list”**. As described in the specification of the present application, the present technique tracks memory access to a card table. Then, when garbage collection is requested, this information is used to correlate the memory accesses to one of a plurality of bundles. Thus, as further described in the specification, by tracking the memory access to the card table, the present technique does not have the performance overhead of locating

and setting a card bundle each time a store operation is performed in the code (see Figure 1 – Prior Art).

The Nagarajan reference discloses a method for setting card tables without having to maintain a large contiguous heap (Col. 2, lines 9-11). In contrast with the Examiner's contention that paragraph [0042], lines 5-7 and Figure 5, element 504 in the Nagarajan reference discloses **"identifying at least one marked bundle out of the plurality of bundles based on the list"**, the Applicant contends that the cited portion in the Nagarajan reference actually discloses the process performed when a store operation is encountered. This argument is reinforced by noting the heading for paragraph [0042] states "Marking Card Table Entries". Therefore, Nagarajan discloses that the store operation determines the segment address (step 504) and then determines the card index within the card table (506). The store operation then accesses the card table within the segment (508) and marks the card table at the index (step 510). Thus, the Nagarajan reference discloses that the segment must be determined for every store operation that is performed. In contrast, as recited in Claim 1, a bundle is determined based on the list requested by the garbage collection process. Thus, as explained in the specification of the present application, the store operation does not perform any specific actions related to bundles. Rather, the card table is tracked. The garbage collection process then uses information obtained from the tracking mechanism to identify the bundles and the card table is used to identify the cards.

The Applicant further contends that the Nagarajan reference actually teaches away from the present technique. The Nagarajan reference notes that **"maintaining a single monolithic card table for the entire heap would require time-consuming operations to locate entries in the card table, to update the card table, and also**

waste space covering unused portions of the native heap”. The Applicant contends that this is because the Nagarajan reference discloses that the store operation is required to handle the segments (bundles). To further explain what the Nagarajan reference classifies as a manageable heap, the Applicant draws the Examiner’s attention to paragraph [0034] that discloses that segments are typically 64Kbytes in size. In contrast, as stated in paragraph [0042] of the present application, the present ephemeral garbage collection utilizes bundles without incurring the overhead of prior attempts. This allows the present ephemeral garbage collection *to operate efficiently with any heap size, in particular, large heaps*. In one embodiment described in the present application, a 4 giga-byte memory heap is implemented by having 16 Mbytes of card table memory with a card size of 32 bytes and where a bundle encompasses 4096*8 cards. Paragraph [0043].

Thus, as recited in amended Claim 1, the instructions for performing ephemeral garbage collection comprises **“requesting a list from a tracking mechanism, the list identifying memory locations that have been written into since the last ephemeral garbage collection”, “each memory location corresponding to one of a plurality of cards associated with a card table”, and “identifying at least one marked bundle based on the list”**. The amendments clarify that the garbage collection process “request[s] a list from a tracking mechanism, the list identifying memory locations” and “each memory location corresponding to one of a plurality of cards associated with a card table”. In addition, the garbage collection process identifies bundles based on the list.

In contrast, the Nagarajan reference discloses identifying bundles during the store operation. For at least the reasons discussed above, Claim 1 is allowable.

Claims 2-4, 6, and 8 depend from Claim 1 and are allowable as depending from an allowable base claim. These claims are also allowable for their own recited features which, in combination with those recited in Claim 1, are neither shown nor suggested by the Nagarajan reference. For example, Claim 2 recites “wherein the tracking mechanism comprises a write-watch mechanism”. As should be apparent from the discussion above, the store operation that is performed each time a store operation is encountered is not the same as the garbage collection process and is not the same as the tracking mechanism. The garbage collection process may utilize information (i.e., marked cards) that was performed during the store operation and the tracking, but they are not the same process. Thus, the Examiner’s contention that the “reference updating mechanism” is analogous to “write-watch mechanism” is incorrect. As explained above, the reference updating mechanism disclosed in the Nagarajan reference must understand the concept of segments (bundles), but the write-watch mechanism does not need to understand the concept of bundles. Rather, it tracks the access to the card table. Similarly, the Examiner’s contention that “the ‘garbage collector’ must request the ‘reference updating mechanism’ is incorrect. As to Claim 8, the Applicant notes that the cited portion does not disclose anything about a “bundle corresponds to a number of cards that are **tracked using a page of memory storing the card table**” (emphasis added).

For at least the reasons discussed above, Claims 2-4, 6, and 8 are allowable.

Claim 19 has been amended to clarify the elements that are not disclosed by the Nagarajan reference. For convenience, Claim 19 is reproduced below with portions in bold to better emphasize some of the elements that are not disclosed in the Nagarajan reference.

19. A system for performing ephemeral garbage collection, the system comprising:

a processor; and

a memory into which a plurality of instructions are loaded and into which a plurality of objects are dynamically allocated, the memory having a heap into which the objects are allocated, the heap being divided into a plurality of cards which are grouped into a plurality of bundles, each card being associated with one or more of the plurality of objects; wherein upon execution of the plurality of instructions by the processor, the system being configured to:

request a list from a tracking mechanism, the list identifying memory locations that have been written into since a last garbage collection cycle, each memory location corresponding to one of the plurality of cards associated with a card table;

identify at least one marked bundle based on the list, wherein the marked bundle represents a subset of the plurality of cards;

determine, for each marked bundle, at least one marked card within the marked bundle, the at least one marked card indicating that one or more objects associated with the marked card has been accessed;

determine, for each marked card, the one or more objects that has been accessed and

performing garbage collection upon the one or more accessed objects.

The Examiner contends that the Nagarajan reference anticipates Claim 19. Claim 19 has been amended in a similar manner as Claim 1. Accordingly, for all of the reasons discussed above with regards to Claim 1, this claim is allowable.

Claims 20-22 depend from Claim 19 and are allowable as depending from an allowable base claim. These claims are also allowable for their own recited

features, which , in combination with those recited in Claim 19, are neither shown nor suggested by the Nagarajan reference.

Claim Rejections Under 35 USC §103(a)

Claims 5-7 were rejected under 35 U.S.C. §103(a) as being unpatentable over the Nagarajan reference in view of U.S. Patent No. 6,510,440 to Alpern (hereinafter referred to as the Alpern reference). Claims 9-10 and 23-24 were rejected under 35 U.S.C. §103(a) as being unpatentable over the Nagarajan reference in view of “A Lifetime-based Garbage Collector for LISP Systems on General-Purpose Computers” by Patrick G. Sobalvarro (hereinafter referred to as the Sobalvarro reference). Claim 11 was rejected under 35 U.S.C. §103(a) as being unpatentable over the Nagarajan reference in view of “Garbage Collection, Algorithms for Automatic Dynamic Memory Management” by Jones et. al. (hereinafter referred to as the Jones reference). Claims 12-17 were rejected under 35 U.S.C. §103(a) as being unpatentable over the Nagarajan reference in view of U.S. Patent No. 6,845,437 to Borman (hereinafter referred to as the Borman reference). Claim 18 was rejected under 35 U.S.C. §103(a) as being unpatentable over the Nagarajan reference in view of the Borman reference, in further view of the Alpern reference.

In overview, as stated in MPEP § 2143, to establish a prima facie case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach

or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure. In re Vaeck, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

Further, as stated in MPEP § 2143.01, obviousness can only be established by combining or modifying the teachings of the prior art to produce the claimed invention where there is some teaching, suggestion, or motivation to do so found either in the references themselves or in the knowledge generally available to one of ordinary skill in the art. In re Fine, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988); In re Jones, 958 F.2d 347, 21 USPQ2d 1941 (Fed. Cir. 1992). The mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. In re Mills, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990).

Therefore, "all words in a claim must be considered in judging the patentability of that claim against the prior art." In re Wilson, 424 F.2d 1382, 165 USPQ 494, 496 (CCPA 1970). If an independent claim is nonobvious under 35 U.S.C. 103, then any claim depending therefrom is nonobvious. In re Fine, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988).

With this legal framework in mind, the Applicant traverses each of the rejections.

Claims 5 and 7 depend from Claim 1 and are allowable as depending from an allowable base claim as discussed above. These claims are also allowable for their own recited features which, in combination with those recited in Claim 1, are neither shown nor suggested by the Nagarajan reference alone or with any

permissible combination with the prior art of record, including the Alpern reference. Thus, even if both of these references could be combined, their teachings do not suggest Claims 5 and 7. In addition, there is no suggestion or motivation to combine these references.

In fact, the Applicant contends that the Alpern reference teaches away from card making. Therefore, the Alpern reference can not be analogous art because the present application implements card marking. In support of this proposition, the Applicant draws the Examiner's attention to Col. 4, lines 45-53, which states that "the card marking imposes too much of a burden on the collection process in the interest of minimizing the cost for the first store of required information". The Alpern reference then provides "alternatives to card marking" using a buffer scheme. Col. 4, lines 54-56. The Alpern reference then discloses their buffer scheme technique. The Applicant reiterates that there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Thus, not only do these references not teach or suggest Claims 5 and 7, the Examiner has impermissibly combined two references. Therefore, the Applicant respectfully submits that the §103 rejections of Claims 5 and 7 is improper, and respectfully requests reconsideration and withdrawal of this rejection.

Claims 9-10 and 23-24 depend from independent Claims 1 and 19, respectively, and are allowable as depending from an allowable base claim as discussed above. These claims are also allowable for their own recited features which, in combination with those recited in their respective independent claims, are

neither shown nor suggested by the Nagarajan reference alone or with any permissible combination of the prior art of record, including the Sobalvarro reference. Thus, even if both of these references could be combined, their teachings do not suggest Claims 9-10 and 23-24. Therefore, the Applicant respectfully submits that the §103 rejections of Claims 9-10 and 23-24 is improper, and respectfully requests reconsideration and withdrawal of this rejection.

Claim 11 depends from independent Claim 1 and is allowable as depending from an allowable base claim as discussed above. This claim is also allowable for its own recited features which, in combination with those recited in Claim 1, are neither shown nor suggested by the Nagarajan reference alone or with any permissible combination of the prior art of record, including the Jones reference. Thus, even if both of these references could be combined, their teachings do not suggest Claim 11. Therefore, the Applicant respectfully submits that the §103 rejection of Claim 11 is improper, and respectfully requests reconsideration and withdrawal of this rejection.

Claim 12 has been amended to clarify the elements that are not taught or suggested by the Nagarajan reference in combination with the permissible prior art of record, including the Borman reference. For convenience, Claim 12 is reproduced below with portions in bold to better emphasize some of the elements that are not taught or suggested in the prior art of record.

12. A method for executing statements within a program to support ephemeral garbage collection, the method comprising:

specifying a range of card table memory to watch during program execution, the card table memory identifying a plurality of cards, each card being associated with one or more objects allocated within a memory heap, **the memory heap being divided into the plurality of cards with each card being grouped into one of a plurality of bundles**; and

for each store statement within the program, storing a value at a memory location within the heap memory based on the store statement, marking one of the plurality of cards within the card table memory based on the memory location, and **tracking access to the range of card table memory**.

The Examiner contends that the Nagarajan reference in view of the Borman reference makes Claim 12 obvious. As shown above, amended independent Claim 12 recites “**specifying a range of card table memory to watch during program execution**”, “**the memory heap being divided into the plurality of cards with each card being grouped into one of a plurality of bundles**” and “**for each store statement within the program ... tracking access to the card table memory**”. As described above, a store process is performed whenever a store operation is encountered during a program’s execution. At some point, a garbage collection process is requested to free up some memory. Claim 12 is directed at the store process. Thus, as further described in the specification, by tracking the memory access to the card table, the present technique does not have the performance overhead of locating and setting a card bundle each time a store operation is encountered in the code (see Figure 1 – Prior Art). Claim 12 recites “**for each store statement within the program ... tracking access to the range of card table memory**”.

The Applicant agrees with the Examiner that the Nagarajan reference does not disclose "specifying a range of card table memory to watch during program execution". However, the Applicant disagrees with the Examiner that the Nagarajan reference in combination with the Borman reference teaches or suggests this limitation and several other limitations recited in Claim 12.

The Examiner has focused on the range checking disclosed in the Borman reference and then stated that the elimination of range checks "in essence specifies the entire size of the card table as the "range". The Applicant contends that the disclosure of "range checks" in the Borman reference does not teach or suggest "specifying a range of card table memory to watch during program execution" as recited in Claim 12. To help explain the Applicant's position, a brief summary of the pertinent portions of the Borman reference are provided.

The Borman reference is directed at the problem where a store operation may occur at an address that is not within the heap. Col. 3, lines 40-44. The Borman reference then explains that one technique to handle this situation is by making the card table big enough to map the whole addressing range and then check only those portions of the card table that correspond to the heap for possible updates. Col. 3, lines 56-60. However, when the address space is large, having a card table that maps to the whole address range is problematic. Range checks may be added to the store operation to ensure that an address is within the heap before calculating the card index. However, this decreases performance. Col. 3, line 62-Col. 4, line 4. The technique disclosed in the Borman reference divides the entire memory into M segments and a card table comprises a set of n cards. Interestingly, however, the number of segments M is greater than the number of cards N. As a result, one card may have multiple memory segments assigned to it.

This technique then eliminates the need for range checks. Col. 4, lines 13-35. Thus, the Borman reference discloses a cyclic mapping of memory space onto the card table. Col. 4, lines 45-46. As described, the range checks disclosed in the Borman reference refer to checking whether the memory associated with the store operation is within the heap.

Based on the foregoing, the Examiner's contention that eliminating the range checks in essence specifies the entire size of the card table as the range, does not have merit. Borman actually discloses "specifying the entire memory" not just the heap. Therefore, this can not possibility teach or suggest "specifying a range of card table memory" as recited in Claim 12. In addition, there is no teaching or suggestion in either the Nagarajan reference or the Borman reference that the range of card table memory is watched during program execution and **"for each store statement within the program ... tracking access to the range of card table memory"**. In addition, the neither reference teaches or suggests **"the memory heap being divided into the plurality of cards with each card being grouped into one of a plurality of bundles"**. Instead, in order to achieve their cyclic approach, the Borman reference teaches to assigned cards to multiple segments and have more segments then cards.

Thus, even if these references could be combined, their teachings do not teach or suggest Claim 12. Therefore, the Applicant respectfully submits that the §103 rejections of Claim 12 is improper, and respectfully requests reconsideration and withdrawal of this rejection.

Claims 13-18 depends from independent Claim 12 and are allowable as depending from an allowable base claim as discussed above. These claims are also

allowable for their own recited features which, in combination with those recited in Claim 12, are neither shown nor suggested by the Nagarajan reference alone or with any permissible combination of the prior art of record, including the Borman reference and the Alpern reference. Thus, even if these references could be combined, their teachings do not suggest Claims 13-18. Therefore, the Applicant respectfully submits that the §103 rejections of Claim 13-18 is improper, and respectfully requests reconsideration and withdrawal of this rejection.

Conclusion

Applicant has considered the other references cited by the Examiner in the Office Action. None of these references appear to affect the patentability of Applicant's claims. By the foregoing remarks, Applicant believes that all pending Claims 1-20 are allowable and the application is in condition for allowance. Therefore, a Notice of Allowance is respectfully requested. Should the Examiner have any further issues regarding this application, the Examiner is requested to contact the undersigned attorney for the Applicant at the telephone number provided below.

Respectfully Submitted,

Dated: August 7, 2006

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